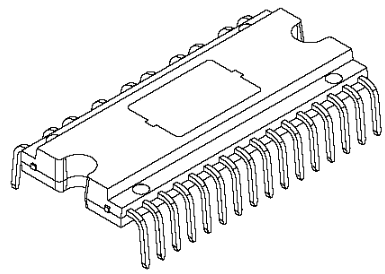
TOSHIBA Intelligent Power Device

High Voltage Monolithic Silicon Power IC

TPD4144K

The TPD4144K is a DC brush less motor driver using high voltage PWM control. It is fabricated by high voltage SOI process. It is three-shunt resistor circuit for current sensing. It contains level shift high-side driver, low-side driver, IGBT outputs, FRDs and protective functions for over-current circuit and under voltage protection circuits and thermal shutdown circuit. It is easy to control a DC brush less motor by just putting logic inputs from a MPU or motor controller to the TPD4144K.



HDIP26-P-1332-2.00

Weight: 3.8 g (typ.)

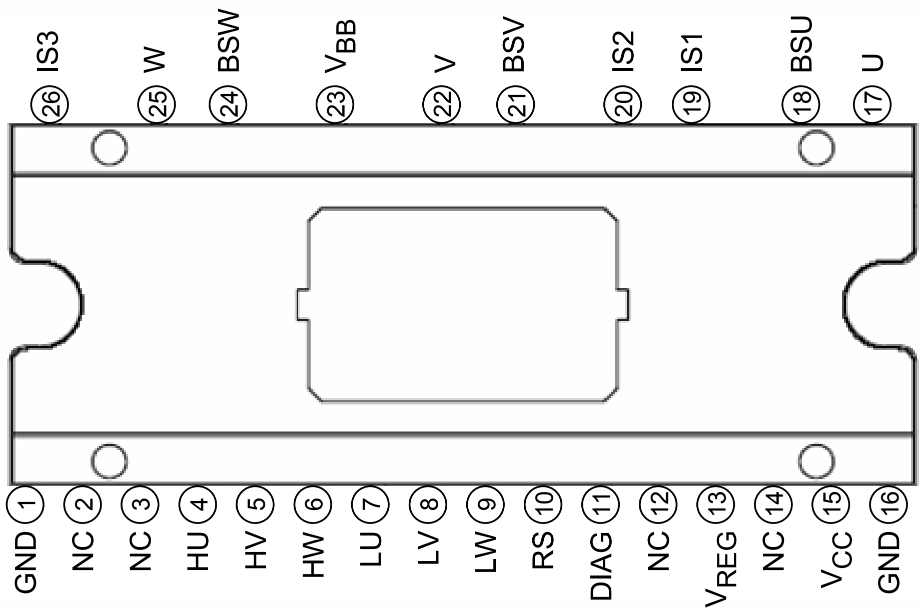
Features

- High voltage power side and low voltage signal side terminal are separated.
- It is the best for current sensing in three shunt resistance.
- Bootstrap circuit gives simple high-side supply.
- Bootstrap diodes are built in.
- A dead time can be set as a minimum of 1.4 μs, and it is suitable for a Sine-wave from drive.
- 3-phase bridge output using IGBTs.
- FRDs are built in.
- Included over-current and under-voltage protection, and thermal shutdown.
- The regulator of 7 V (typ.) is built in.
- Package: 26-pin DIP.

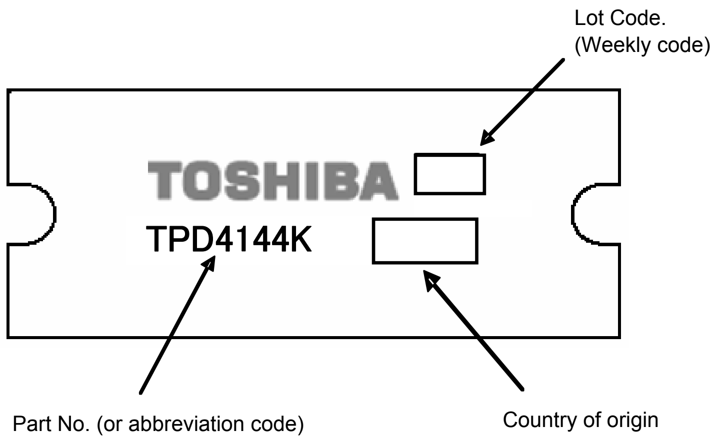
This product has a MOS structure and is sensitive to electrostatic discharge. When handling this product, ensure that the environment is protected against electrostatic discharge.

Start of commercial production
2012-01

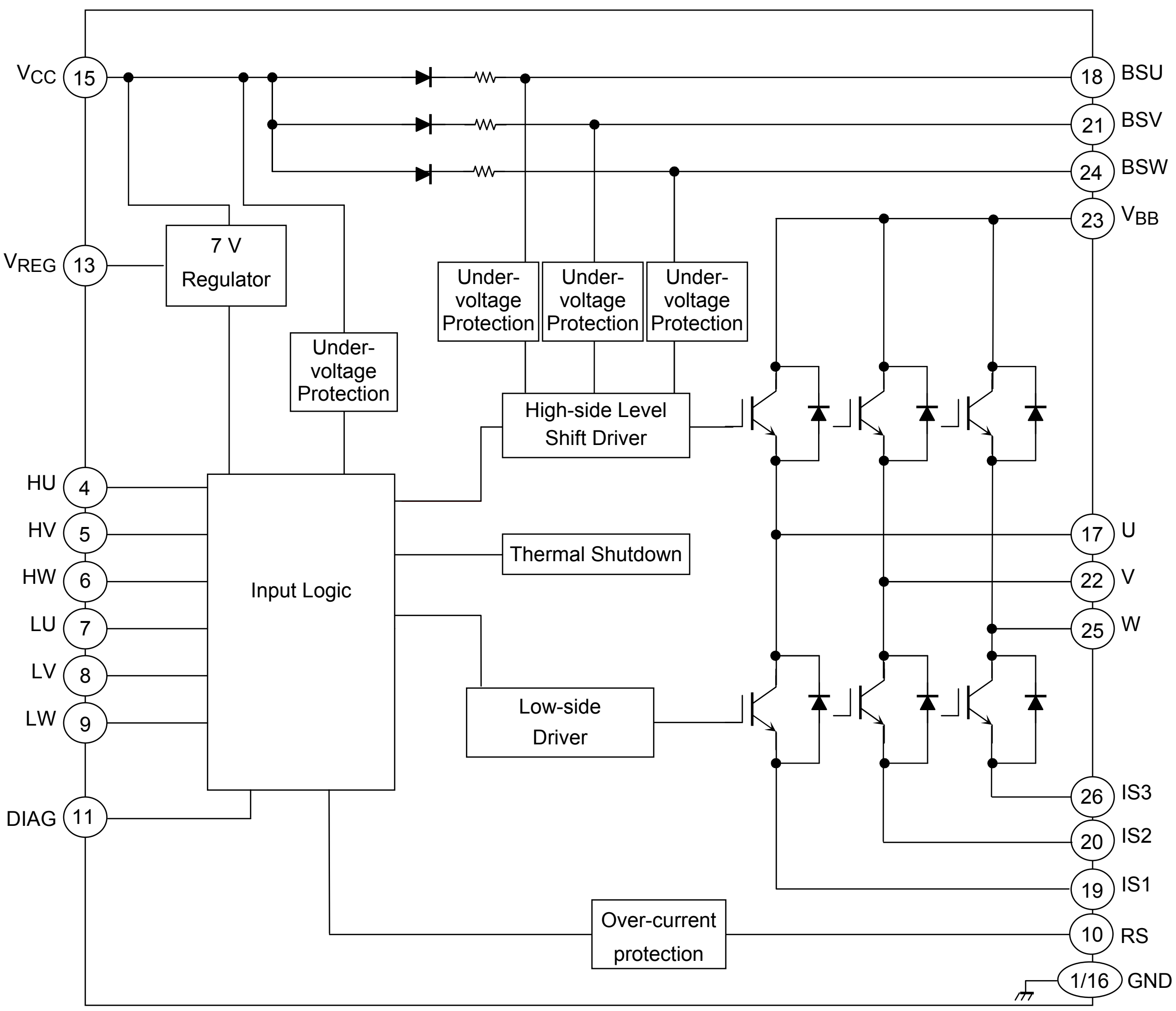
Pin Assignment



Marking



Block Diagram

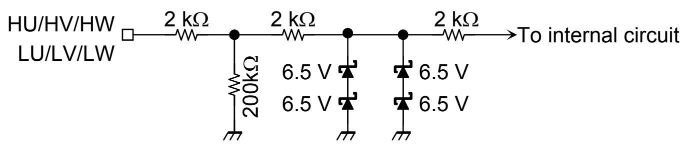


Pin Description

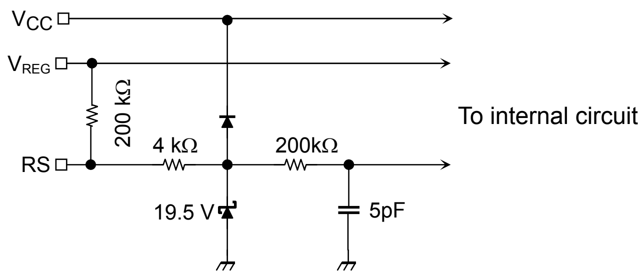
Pin No.	Symbol	Pin Description
1	GND	Ground pin.
2	NC	Unused pin, which is not connected to the chip internally.
3	NC	Unused pin, which is not connected to the chip internally.
4	HU	The control terminal of IGBT by the high side of U. It turns off less than 1.5 V. It turns on more than 2.5 V.
5	HV	The control terminal of IGBT by the high side of V. It turns off less than 1.5 V. It turns on more than 2.5 V.
6	HW	The control terminal of IGBT by the high side of W. It turns off less than 1.5 V. It turns on more than 2.5 V.
7	LU	The control terminal of IGBT by the low side of U. It turns off less than 1.5 V. It turns on more than 2.5 V.
8	LV	The control terminal of IGBT by the low side of V. It turns off less than 1.5 V. It turns on more than 2.5 V.
9	LW	The control terminal of IGBT by the low side of W. It turns off less than 1.5 V. It turns on more than 2.5 V.
10	RS	Over current detection pin.
11	DIAG	With the diagnostic output terminal of open drain , a pull-up is carried out by resistance. It turns on at the time of unusual.
12	NC	Unused pin, which is not connected to the chip internally.
13	V_{REG}	7 V regulator output pin.
14	NC	Unused pin, which is not connected to the chip internally.
15	V_{CC}	Control power supply pin. (15 V typ.)
16	GND	Ground pin.
17	U	U-phase output pin.
18	BSU	U-phase bootstrap capacitor connecting pin.
19	IS1	U-phase IGBT emitter and FRD anode pin.
20	IS2	V-phase IGBT emitter and FRD anode pin.
21	BSV	V-phase bootstrap capacitor connecting pin.
22	V	V-phase output pin.
23	V_{BB}	High-voltage power supply input pin.
24	BSW	W-phase bootstrap capacitor connecting pin.
25	W	W-phase output pin.
26	IS3	W-phase IGBT emitter and FRD anode pin.

Equivalent Circuit of Input Pins

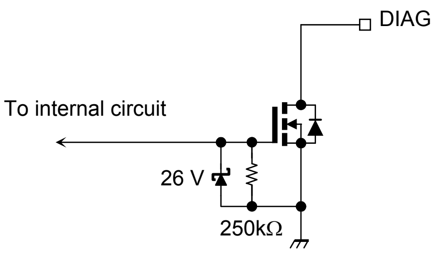
Internal circuit diagram of HU, HV, HW, LU, LV, LW input pins



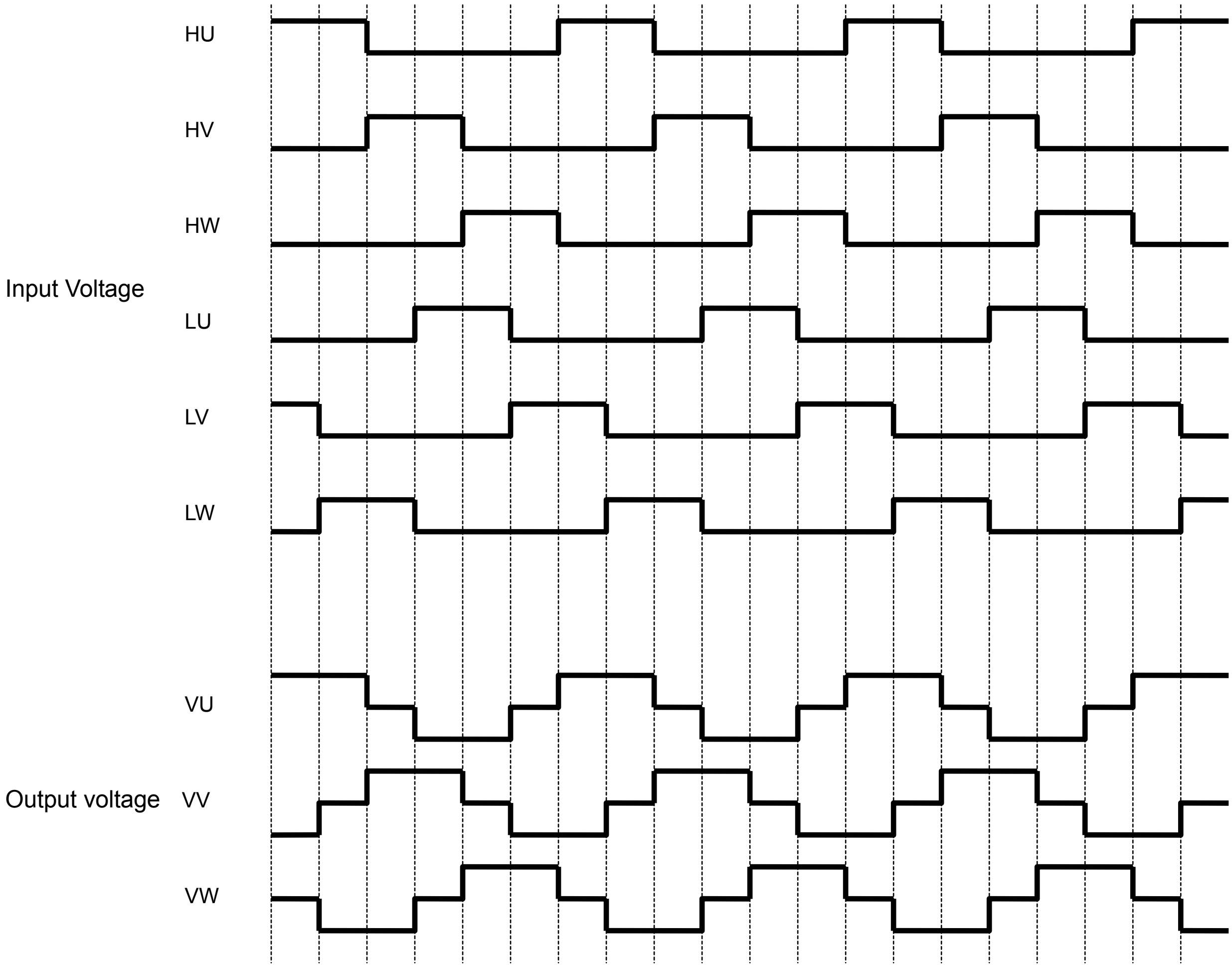
Internal circuit diagram of RS pin



Internal circuit diagram of DIAG pin



Timing Chart



Truth Table

Mode	Input						High side			Low side			DIAG
	HU	HV	HW	LU	LV	LW	U phase	V phase	W phase	U phase	V phase	W phase	
Normal	H	L	L	L	H	L	ON	OFF	OFF	OFF	ON	OFF	OFF
	H	L	L	L	L	H	ON	OFF	OFF	OFF	OFF	ON	OFF
	L	H	L	L	L	H	OFF	ON	OFF	OFF	OFF	ON	OFF
	L	H	L	H	L	L	OFF	ON	OFF	ON	OFF	OFF	OFF
	L	L	H	H	L	L	OFF	OFF	ON	ON	OFF	OFF	OFF
	L	L	H	L	H	L	OFF	OFF	ON	OFF	ON	OFF	OFF
Over-current	H	L	L	L	H	L	OFF	OFF	OFF	OFF	OFF	OFF	ON
	H	L	L	L	L	H	OFF	OFF	OFF	OFF	OFF	OFF	ON
	L	H	L	L	L	H	OFF	OFF	OFF	OFF	OFF	OFF	ON
	L	H	L	H	L	L	OFF	OFF	OFF	OFF	OFF	OFF	ON
	L	L	H	H	L	L	OFF	OFF	OFF	OFF	OFF	OFF	ON
	L	L	H	L	H	L	OFF	OFF	OFF	OFF	OFF	OFF	ON
Thermal shutdown	H	L	L	L	H	L	OFF	OFF	OFF	OFF	OFF	OFF	ON
	H	L	L	L	L	H	OFF	OFF	OFF	OFF	OFF	OFF	ON
	L	H	L	L	L	H	OFF	OFF	OFF	OFF	OFF	OFF	ON
	L	H	L	H	L	L	OFF	OFF	OFF	OFF	OFF	OFF	ON
	L	L	H	H	L	L	OFF	OFF	OFF	OFF	OFF	OFF	ON
	L	L	H	L	H	L	OFF	OFF	OFF	OFF	OFF	OFF	ON
V_{CC} Under-voltage	H	L	L	L	H	L	OFF	OFF	OFF	OFF	OFF	OFF	ON
	H	L	L	L	L	H	OFF	OFF	OFF	OFF	OFF	OFF	ON
	L	H	L	L	L	H	OFF	OFF	OFF	OFF	OFF	OFF	ON
	L	H	L	H	L	L	OFF	OFF	OFF	OFF	OFF	OFF	ON
	L	L	H	H	L	L	OFF	OFF	OFF	OFF	OFF	OFF	ON
	L	L	H	L	H	L	OFF	OFF	OFF	OFF	OFF	OFF	ON
V_{BS} Under-voltage	H	L	L	L	H	L	OFF	OFF	OFF	OFF	ON	OFF	OFF
	H	L	L	L	L	H	OFF	OFF	OFF	OFF	OFF	ON	OFF
	L	H	L	L	L	H	OFF	OFF	OFF	OFF	OFF	ON	OFF
	L	H	L	H	L	L	OFF	OFF	OFF	ON	OFF	OFF	OFF
	L	L	H	H	L	L	OFF	OFF	OFF	ON	OFF	OFF	OFF
	L	L	H	L	H	L	OFF	OFF	OFF	OFF	ON	OFF	OFF

Absolute Maximum Ratings (Ta = 25°C)

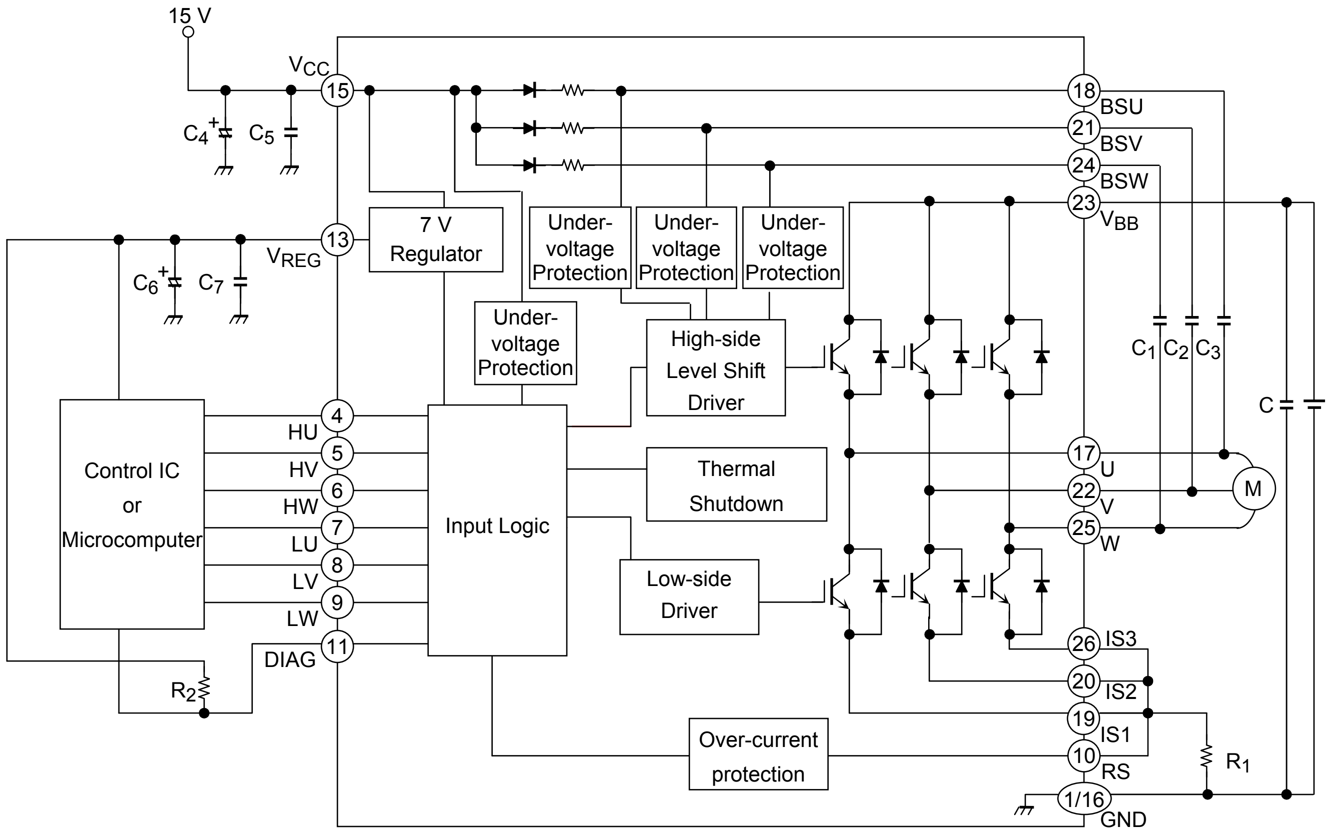
Characteristics		Symbol	Rating	Unit
Power supply voltage		V_{BB}	500	V
		V_{CC}	18	V
Output current (DC)		I_{out}	2	A
Output current (pulse 1ms)		I_{outp}	3	A
Input voltage		V_{IN}	-0.5 to 7	V
V_{REG} current		I_{REG}	50	mA
DIAG voltage		V_{DIAG}	20	V
DIAG current		I_{DIAG}	20	mA
Power dissipation (IGBT1 phase (Tc = 25°C))		$P_{C(IGBT)}$	36	W
Power dissipation (FRD1 phase (Tc = 25°C))		$P_{C(FRD)}$	22	W
Operating junction temperature		T_{jopr}	-40 to 135	°C
Junction temperature		T_j	150	°C
Storage temperature		T_{stg}	-55 to 150	°C

Note: Using continuously under heavy loads (e.g. the application of high temperature/current/voltage and the significant change in temperature, etc.) may cause this product to decrease in the reliability significantly even if the operating conditions (i.e. operating temperature/current/voltage, etc.) are within the absolute maximum ratings and the operating ranges.
Please design the appropriate reliability upon reviewing the Toshiba Semiconductor Reliability Handbook (“Handling Precautions”/“Derating Concept and Methods”) and individual reliability data (i.e. reliability test report and estimated failure rate, etc).

Electrical Characteristics (Ta = 25°C)

Characteristics	Symbol	Test Condition	Min	Typ.	Max	Unit
Operating power supply voltage	V_{BB}	—	50	280	450	V
	V_{CC}	—	13.5	15	16.5	
Current dissipation	I_{BB}	V_{BB} = 450 V	—	—	0.5	mA
	I_{CC}	V_{CC} = 15 V	—	0.8	5	
Bootstrap Current dissipation	$I_{BS (ON)}$	V_{BS} = 15 V, high side ON	—	210	410	μA
	$I_{BS (OFF)}$	V_{BS} = 15 V, high side OFF	—	180	370	
Input voltage	V_{IH}	V_{IN} = "H", V_{CC} = 15 V	2.5	—	—	V
	V_{IL}	V_{IN} = "L" , V_{CC} = 15 V	—	—	1.5	
Input current	I_{IH}	V_{IN} = 5 V	—	—	150	μA
	I_{IL}	V_{IN} = 0 V	—	—	100	
Output saturation voltage	$V_{CEsat}H$	V_{CC} = 15 V, I_C = 1 A, high side	—	2.3	3.2	V
	$V_{CEsat}L$	V_{CC} = 15 V, I_C = 1 A, low side	—	2.3	3.2	
FRD forward voltage	V_FH	I_F = 1 A, high side	—	2.1	3.1	V
	V_FL	I_F = 1 A, low side	—	2.1	3.1	
BSD forward voltage	$V_{F (BSD)}$	I_F = 500 μA	—	0.8	1.2	V
Regulator voltage	V_{REG}	V_{CC} = 15 V, I_{REG} = 30 mA	6.5	7	7.5	V
Current limiting voltage	V_R	—	0.46	0.5	0.54	V
Current limiting delay time	Dt	—	1.5	3	5	μs
Thermal shutdown temperature	TSD	V_{CC} = 15 V	135	—	185	°C
Thermal shutdown hysteresis	ΔTSD	V_{CC} = 15 V	—	50	—	°C
V_{CC} under voltage protection	$V_{CC}UVD$	—	10	11	12	V
V_{CC} under voltage protection recovery	$V_{CC}UVR$	—	10.5	11.5	12.5	V
V_{BS} under voltage protection	$V_{BS}UVD$	—	8	9	9.5	V
V_{BS} under voltage protection recovery	$V_{BS}UVR$	—	8.5	9.5	10.5	V
DIAG saturation voltage	$V_{DIAGsat}$	I_{DIAG} = 5 mA	—	—	0.5	V
Output on delay time	t_{on}	V_{BB} = 280 V, V_{CC} = 15 V, I_C = 1 A	—	1.2	3	μs
Output off delay time	t_{off}	V_{BB} = 280 V, V_{CC} = 15 V, I_C = 1 A	—	1	3	μs
Dead time	t_{dead}	V_{BB} = 280 V, V_{CC} = 15 V, I_C = 1 A	1.4	—	—	μs
FRD reverse recovery time	t_{rr}	V_{BB} = 280 V, V_{CC} = 15 V, I_C = 1 A	—	150	—	ns

Application Circuit Example



External Parts

Typical external parts are shown in the following table.

Part	Typical	Purpose	Remarks
C_1, C_2, C_3	25 V/2.2 μF	Bootstrap capacitor	(Note 1)
R_1	0.35 Ω ± 1 % (1 W)	Current detection	(Note 2)
C_4	25 V/10 μF	V_{CC} power supply stability	(Note 3)
C_5	25 V/0.1 μF	V_{CC} for surge absorber	(Note 3)
C_6	25 V/1 μF	V_{REG} power supply stability	(Note 3)
C_7	25 V/1000 pF	V_{REG} for surge absorber	(Note 3)
R_2	5.1 kΩ	DIAG pull-up resistor	(Note 4)

Note 1: The required bootstrap capacitance value varies according to the motor drive conditions. The capacitor is biased by V_{CC} and must be sufficiently derated for it.

Note 2: The following formula shows the detection current: $I_O = V_R \div R_1$ (For $V_R = 0.5$ V typ.)
Do not exceed a detection current of 2 A when using this product.
(Please go from the outside in the over current protection.)

Note 3: When using this product, adjustment is required in accordance with the use environment. When mounting, place as close to the base of this product leads as possible to improve the ripple and noise elimination.

Note 4: The DIAG pin is open drain. If not using the DIAG pin, connect to the GND.

Handling precautions

(1) Please control the input signal in the state to which the V_{CC} voltage is steady. Both of the order of the V_{BB} power supply and the V_{CC} power supply are not cared about either.
Note that if the power supply is switched off as described above, this product may be destroyed if the current regeneration route to the V_{BB} power supply is blocked when the V_{BB} line is disconnected by a relay or similar while the motor is still running.

(2) The RS pin connecting the current detection resistor is connected to a comparator in the IC and also functions as a sensor pin for detecting over current. As a result, over voltage caused by a surge voltage, for example, may destroy the circuit. Accordingly, be careful of handling the IC or of surge voltage in its application environment.

Description of Protection Function

(1) Over-current protection

This product incorporates a over-current protection circuit to protect itself against over-current at startup or when a motor is locked. This protection function detects voltage generated in the current detection resistor connected to the RS pin. When this voltage exceeds V_R (=0.5 V typ.), the IGBT output, which is on, temporarily shuts down after a delay time , preventing any additional current from flowing to this product. The next all "L" signal releases the shutdown state.

(2) Under voltage protection

This product incorporates under voltage protection circuits to prevent the IGBT from operating in unsaturated mode when the V_{CC} voltage or the V_{BS} voltage drops.

When the V_{CC} power supply falls to this product internal setting V_{CC}UVD (=11 V typ.), all IGBT outputs shut down regardless of the input. This protection function has hysteresis. When the V_{CC} power supply reaches 0.5 V higher than the shutdown voltage (V_{CC}UVR (=11.5 V typ.)), this product is automatically restored and the IGBT is turned on again by the input. DIAG output is reversed at the time of V_{CC} under-voltage protection. When the V_{CC} power supply is less than 7 V, DIAG output isn't sometimes reversed. When the V_{BS} supply voltage drops V_{BS}UVD (=9 V typ.), the high-side IGBT output shuts down. When the V_{BS} supply voltage reaches 0.5 V higher than the shutdown voltage (V_{BS}UVR (=9.5 V typ.)), the IGBT is turned on again by the input signal.

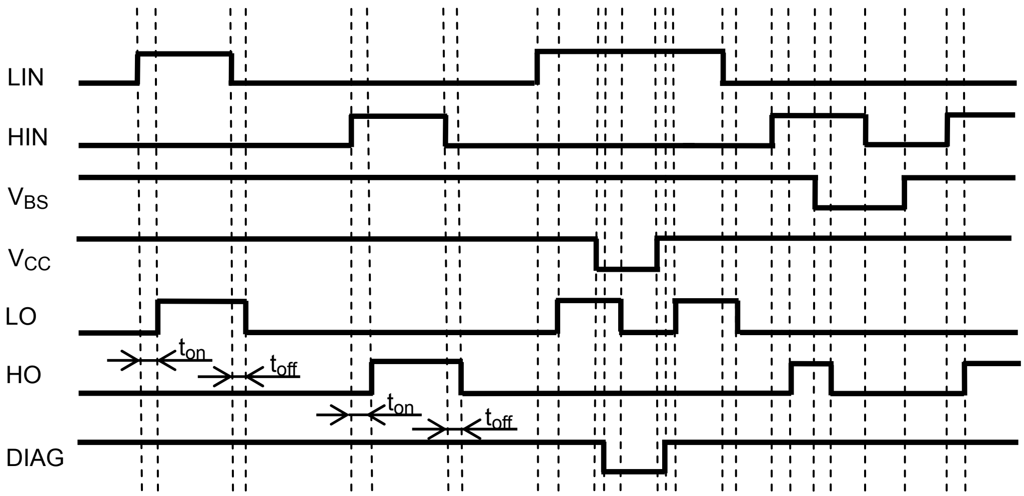
(3) Thermal shutdown

This product incorporates a thermal shutdown circuit to protect itself against the abnormal state when its temperature rises excessively.

When the temperature of this chip rises to the internal setting TSD due to external causes or internal heat generation, all IGBT outputs shut down regardless of the input. This protection function has hysteresis ΔTSD (= 50°C typ.). When the chip temperature falls to TSD − ΔTSD, the chip is automatically restored and the IGBT is turned on again by the input.

Because the chip contains just one temperature detection location, when the chip heats up due to the IGBT, for example, the differences in distance from the detection location in the IGBT (the source of the heat) cause differences in the time taken for shutdown to occur. Therefore, the temperature of the chip may rise higher than the thermal shutdown temperature when the circuit started to operate.

Timing Chart of Under voltage protection



Note: The above timing chart is considering the delay time

Safe Operating Area

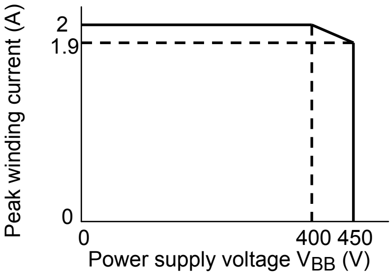
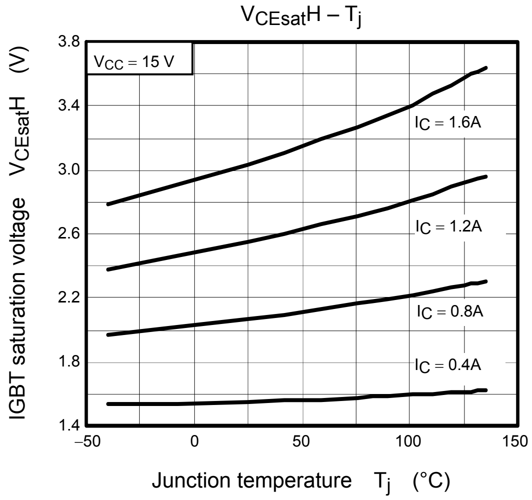
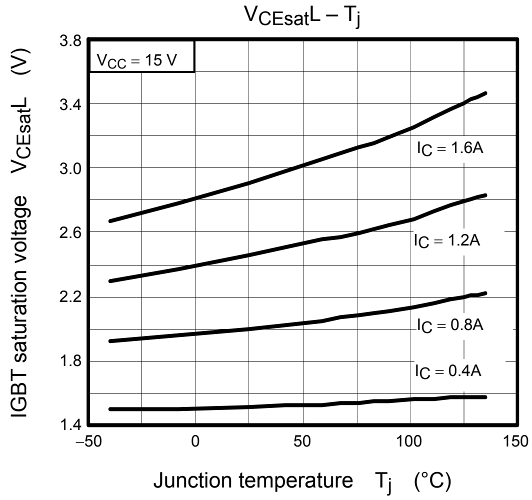
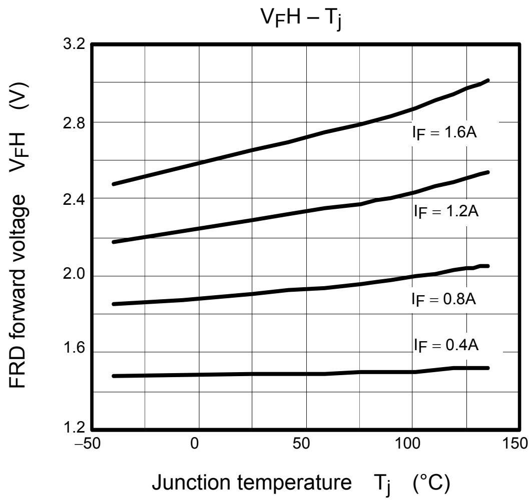


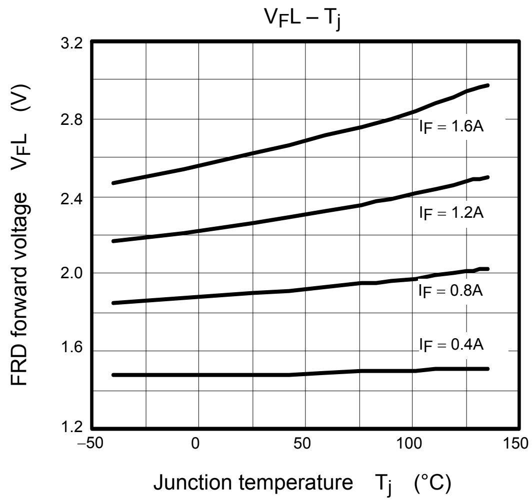
Figure 1 SOA at Tj = 135 °C

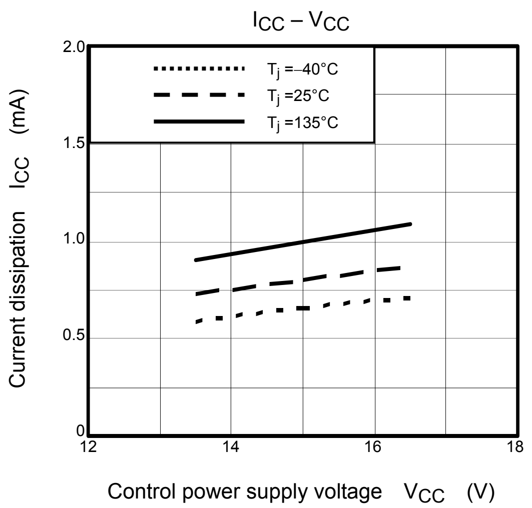
Note 1: The above safe operating areas are Tj = 135 °C (Figure 1).

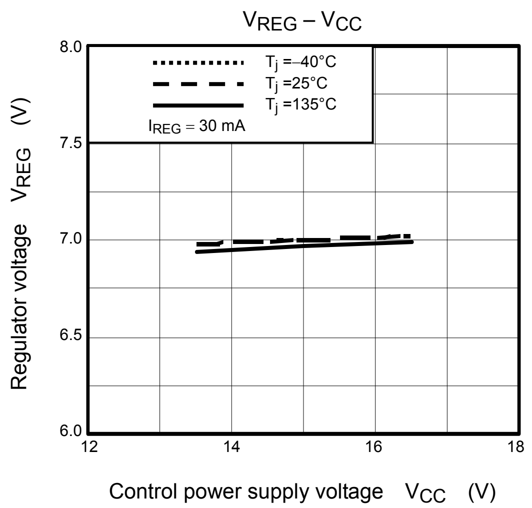

VCEsatH – Tj
VCC = 15 V
IC = 1.6A
IC = 1.2A
IC = 0.8A
IC = 0.4A
IGBT saturation voltage VCEsatH (V)
Junction temperature Tj (°C)

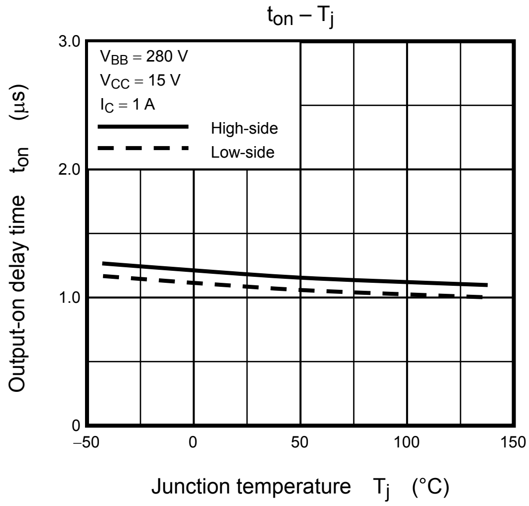

VCEsatL – Tj
VCC = 15 V
IC = 1.6A
IC = 1.2A
IC = 0.8A
IC = 0.4A
IGBT saturation voltage VCEsatL (V)
Junction temperature Tj (°C)

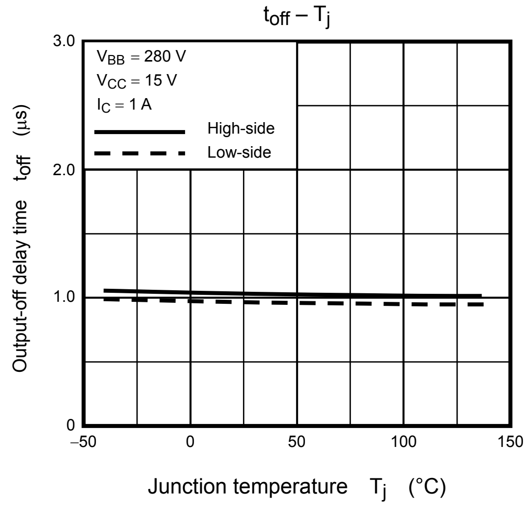

VFH – Tj
IF = 1.6A
IF = 1.2A
IF = 0.8A
IF = 0.4A
FRD forward voltage VFH (V)
Junction temperature Tj (°C)

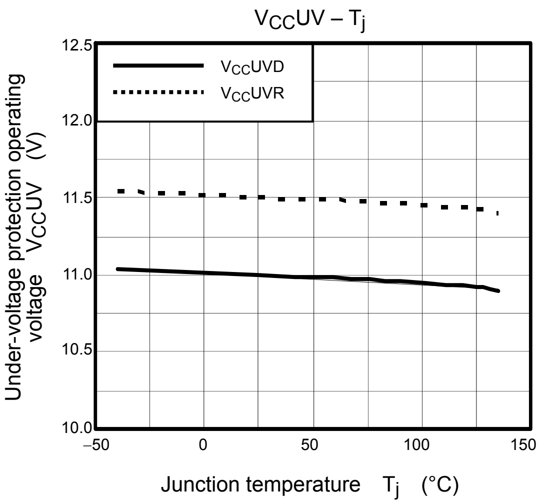

VFL – Tj
IF = 1.6A
IF = 1.2A
IF = 0.8A
IF = 0.4A
FRD forward voltage VFL (V)
Junction temperature Tj (°C)

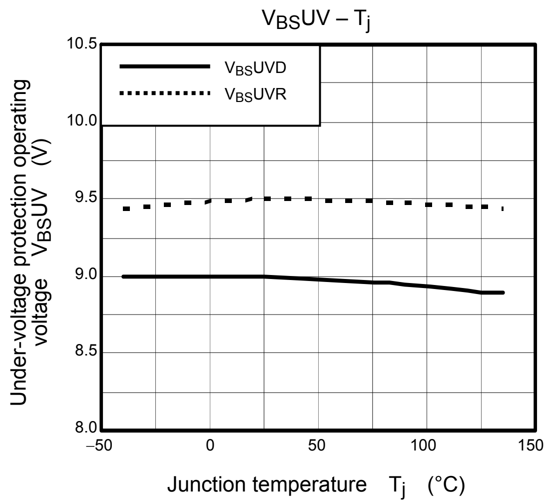

ICC – VCC
Tj =–40°C
Tj =25°C
Tj =135°C
Current dissipation ICC (mA)
Control power supply voltage VCC (V)

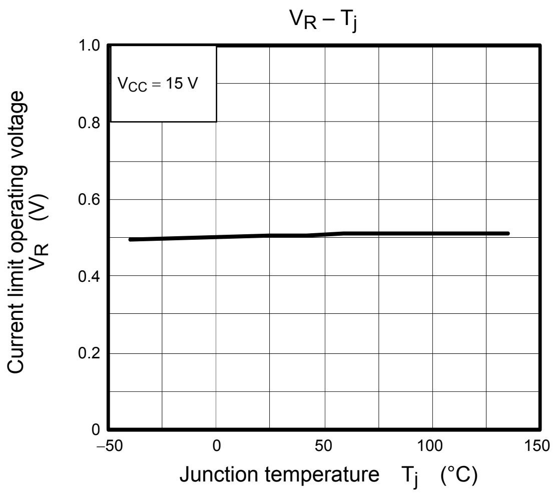

VREG – VCC
Tj =–40°C
Tj =25°C
Tj =135°C
IREG = 30 mA
Regulator voltage VREG (V)
Control power supply voltage VCC (V)

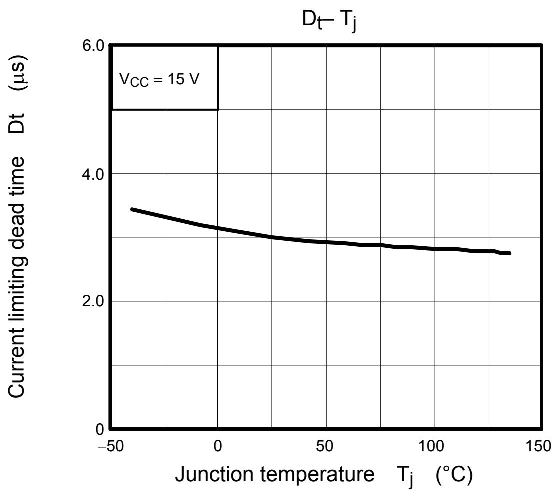

ton – Tj
VBB = 280 V
VCC = 15 V
IC = 1 A
High-side
Low-side
Output-on delay time ton (µs)
3.0
2.0
1.0
0
–50
0
50
100
150
Junction temperature Tj (°C)

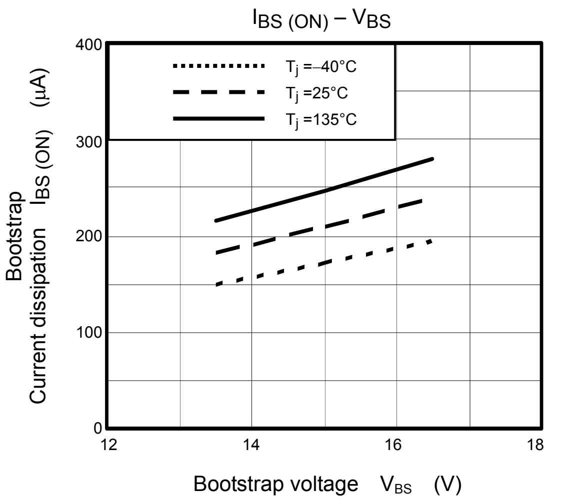

toff – Tj
VBB = 280 V
VCC = 15 V
IC = 1 A
High-side
Low-side
Output-off delay time toff (µs)
3.0
2.0
1.0
0
–50
0
50
100
150
Junction temperature Tj (°C)

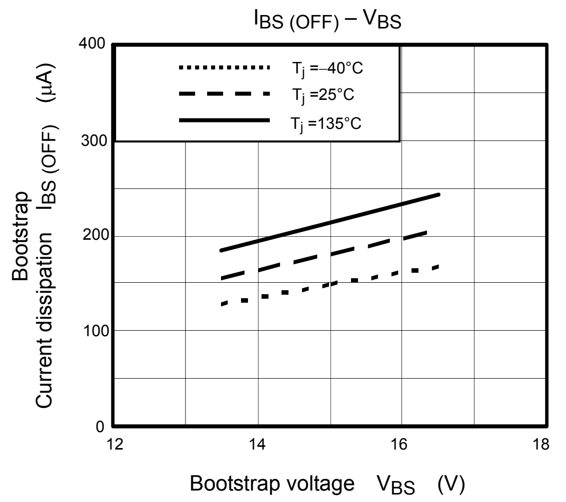

VCCUV – Tj
VCCUVD
VCCUVR
Under-voltage protection operating voltage VCCUV (V)
12.5
12.0
11.5
11.0
10.5
10.0
–50
0
50
100
150
Junction temperature Tj (°C)

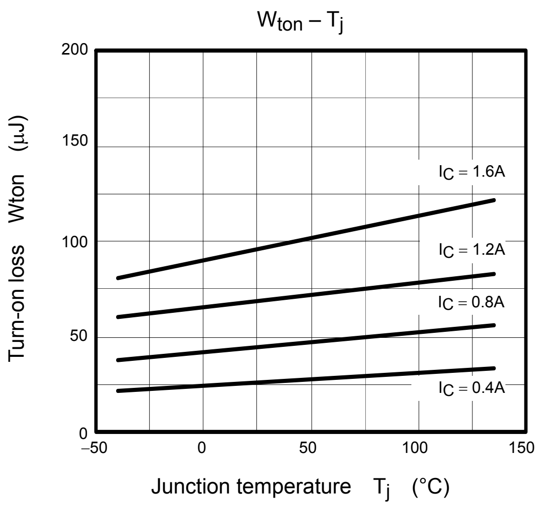

VBSUV – Tj
VBSUVD
VBSUVR
Under-voltage protection operating voltage VBSUV (V)
10.5
10.0
9.5
9.0
8.5
8.0
–50
0
50
100
150
Junction temperature Tj (°C)

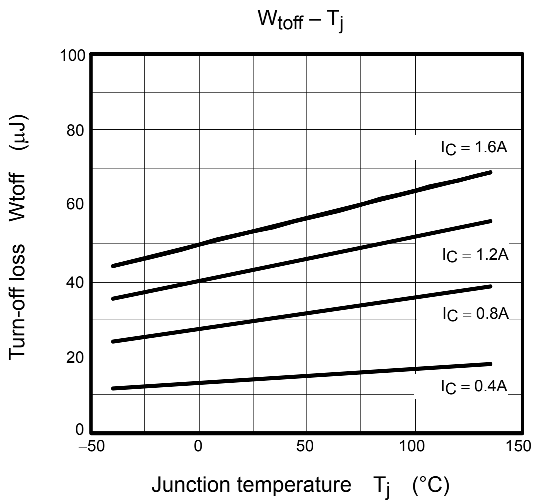

VR – Tj
VCC = 15 V
Current limit operating voltage VR (V)
1.0
0.8
0.6
0.4
0.2
0
–50
0
50
100
150
Junction temperature Tj (°C)


Dt– Tj
VCC = 15 V
Current limiting dead time Dt (µs)
6.0
4.0
2.0
0
–50
0
50
100
150
Junction temperature Tj (°C)


$I_{BS (ON)}$ – V_{BS}
T_j = –40°C
T_j = 25°C
T_j = 135°C
Bootstrap Current dissipation $I_{BS (ON)}$ (μA)
0
100
200
300
400
12
14
16
18
Bootstrap voltage V_{BS} (V)

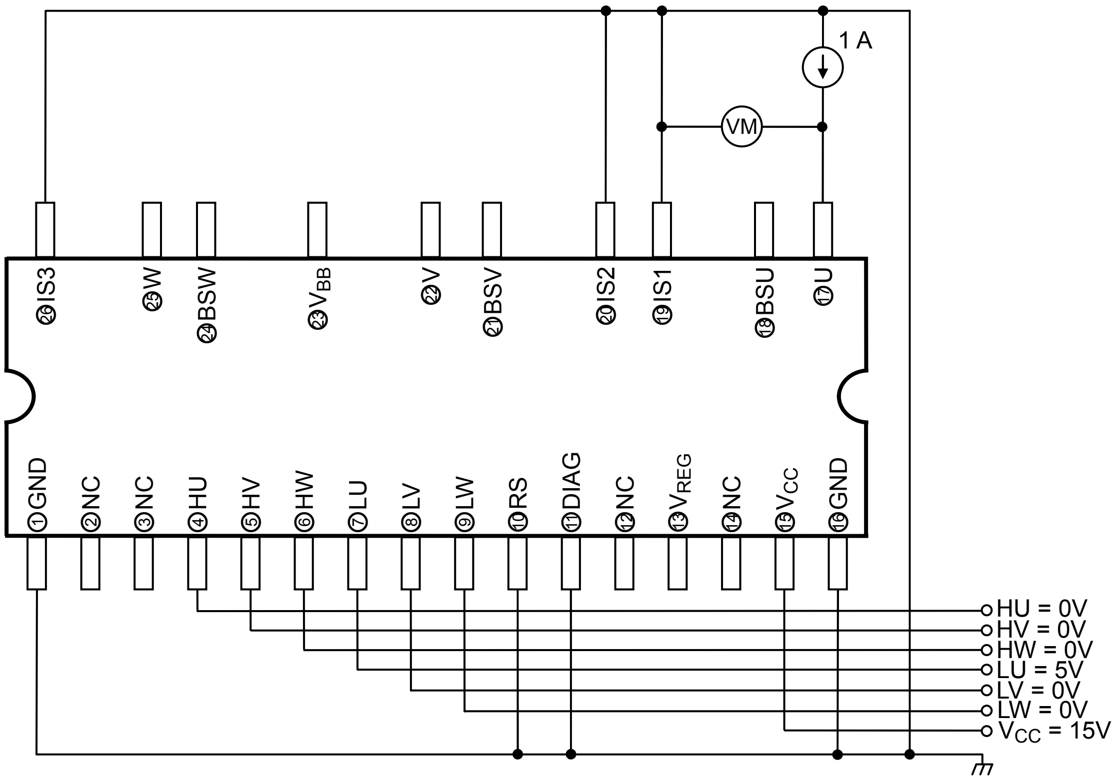

$I_{BS (OFF)}$ – V_{BS}
T_j = –40°C
T_j = 25°C
T_j = 135°C
Bootstrap Current dissipation $I_{BS (OFF)}$ (μA)
0
100
200
300
400
12
14
16
18
Bootstrap voltage V_{BS} (V)


W_{ton} – T_j
I_C = 1.6A
I_C = 1.2A
I_C = 0.8A
I_C = 0.4A
Turn-on loss Wton (μJ)
0
50
100
150
200
–50
0
50
100
150
Junction temperature T_j (°C)

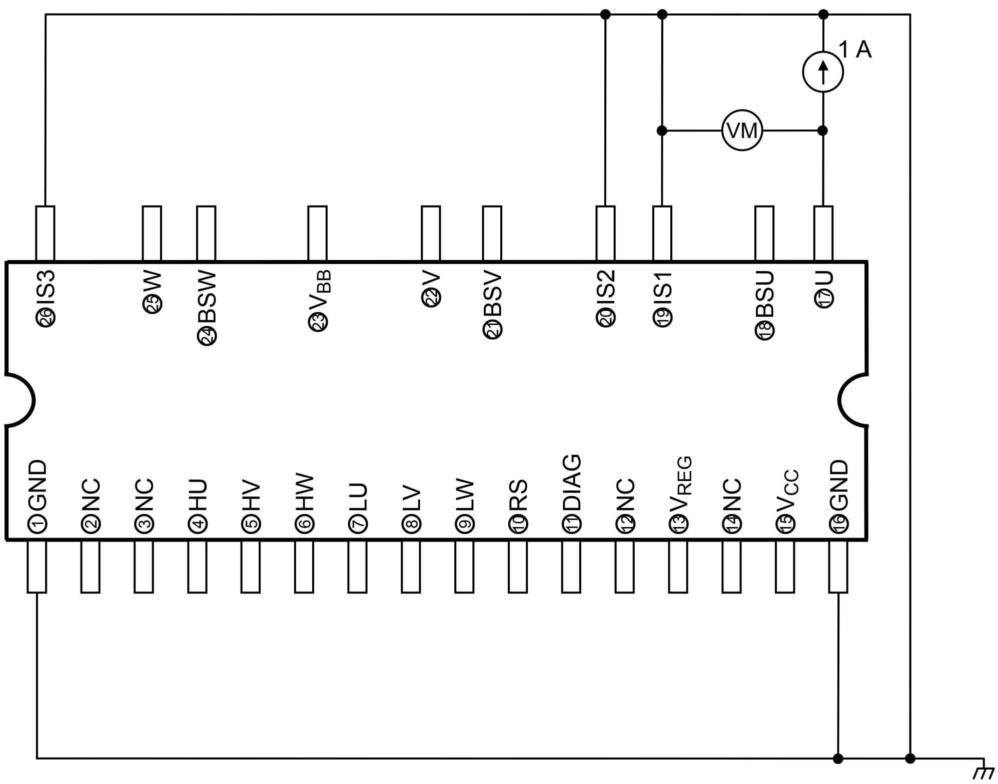

W_{toff} – T_j
I_C = 1.6A
I_C = 1.2A
I_C = 0.8A
I_C = 0.4A
Turn-off loss Wtoff (μJ)
0
20
40
60
80
100
–50
0
50
100
150
Junction temperature T_j (°C)

Test Circuits

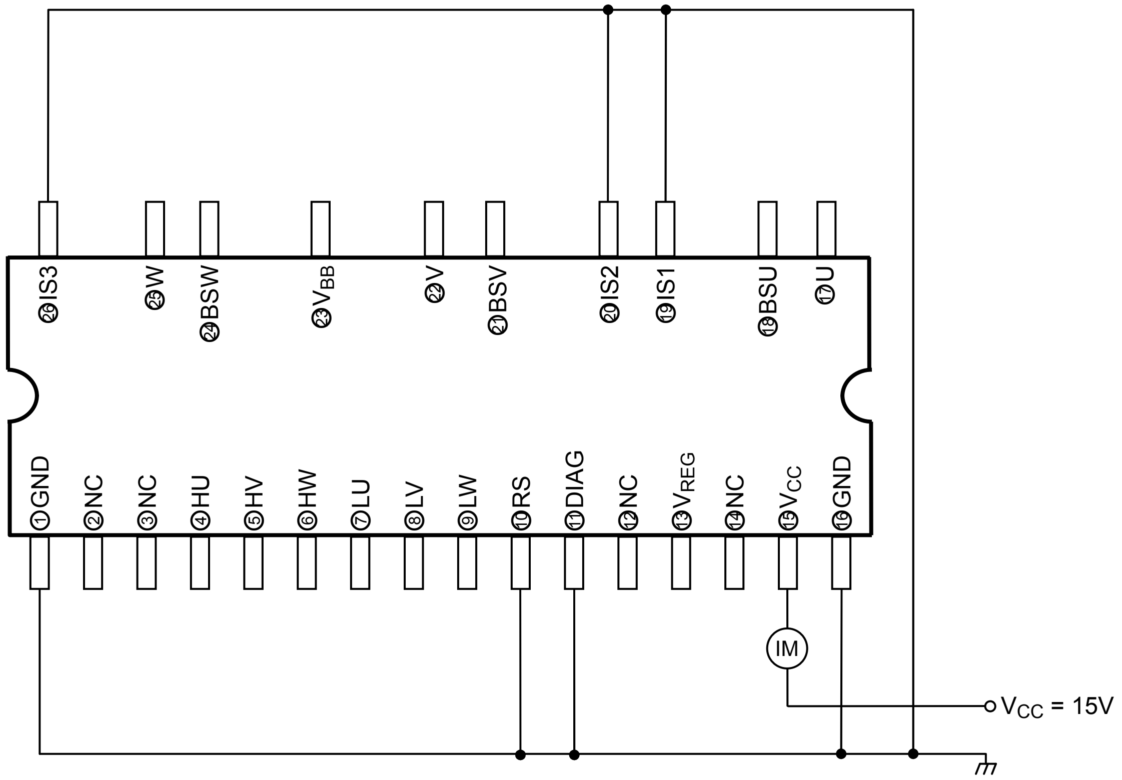
IGBT Saturation Voltage (U-phase low side)



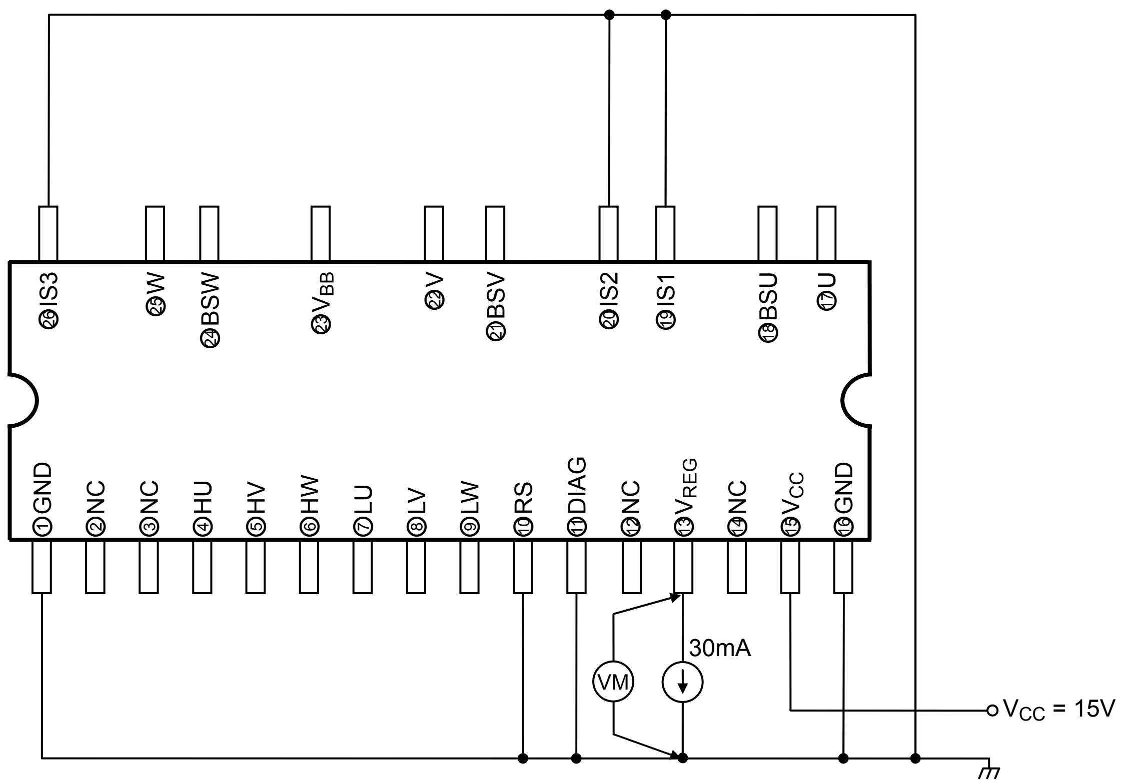
FRD Forward Voltage (U-phase low side)



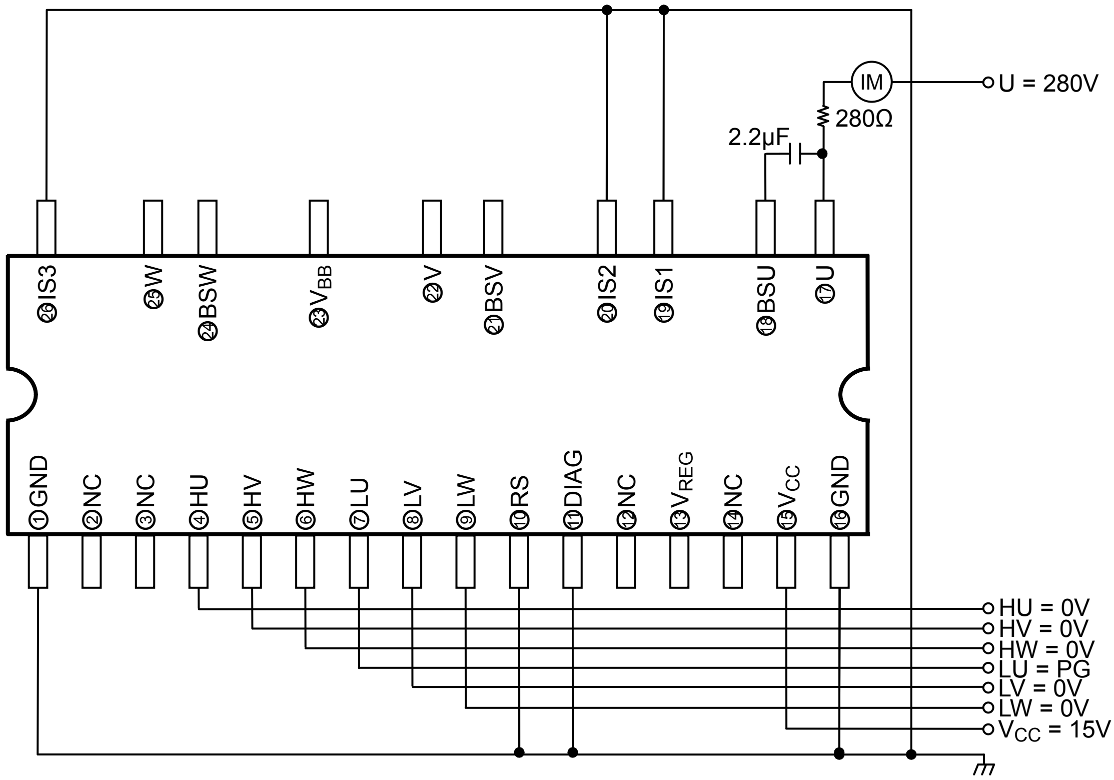
V_{CC} Current Dissipation

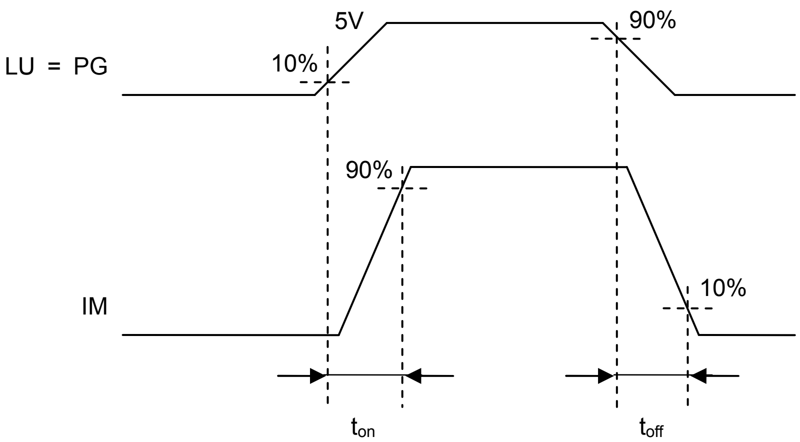


Regulator Voltage

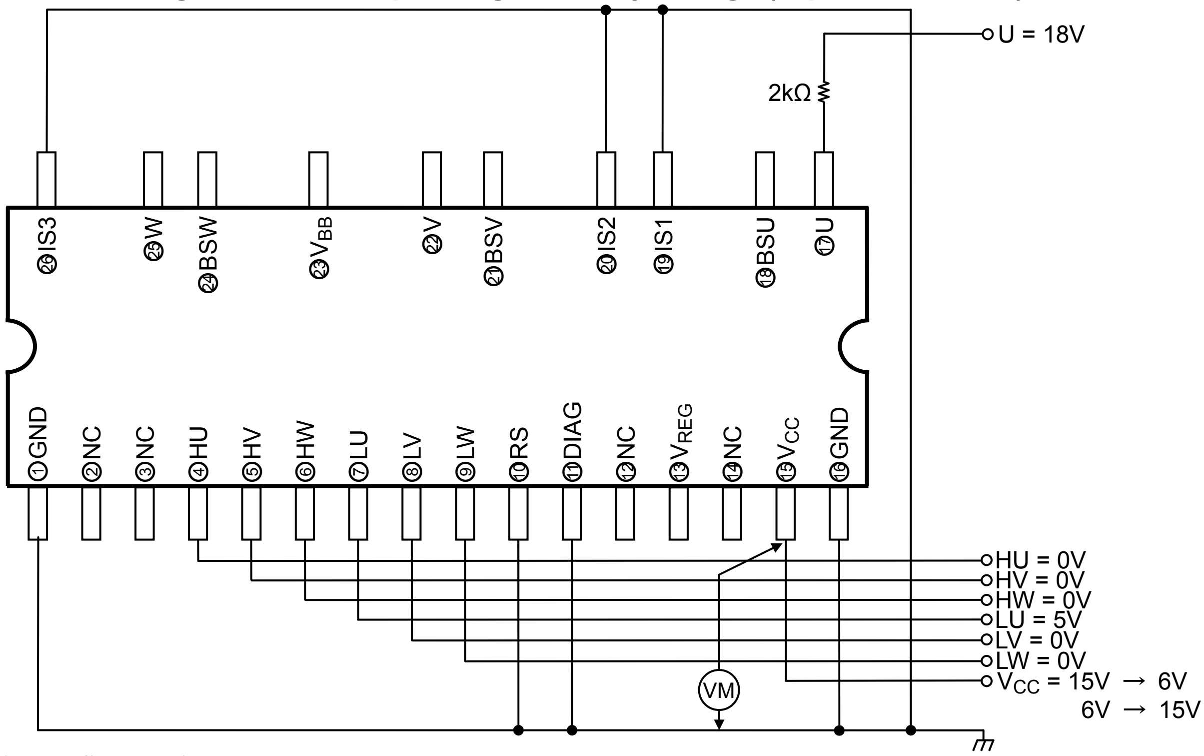


Output ON/OFF Delay Time (U-phase low side)



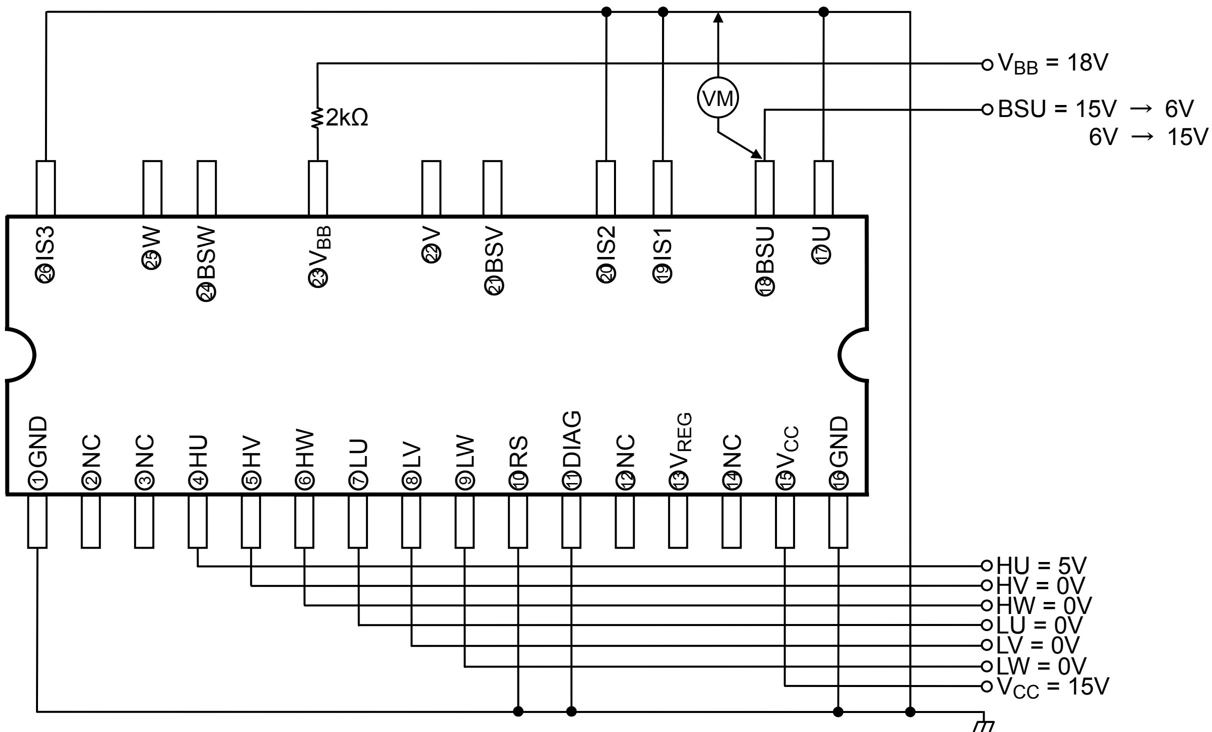


VCC Under-voltage Protection Operating/Recovery Voltage (U-phase low side)



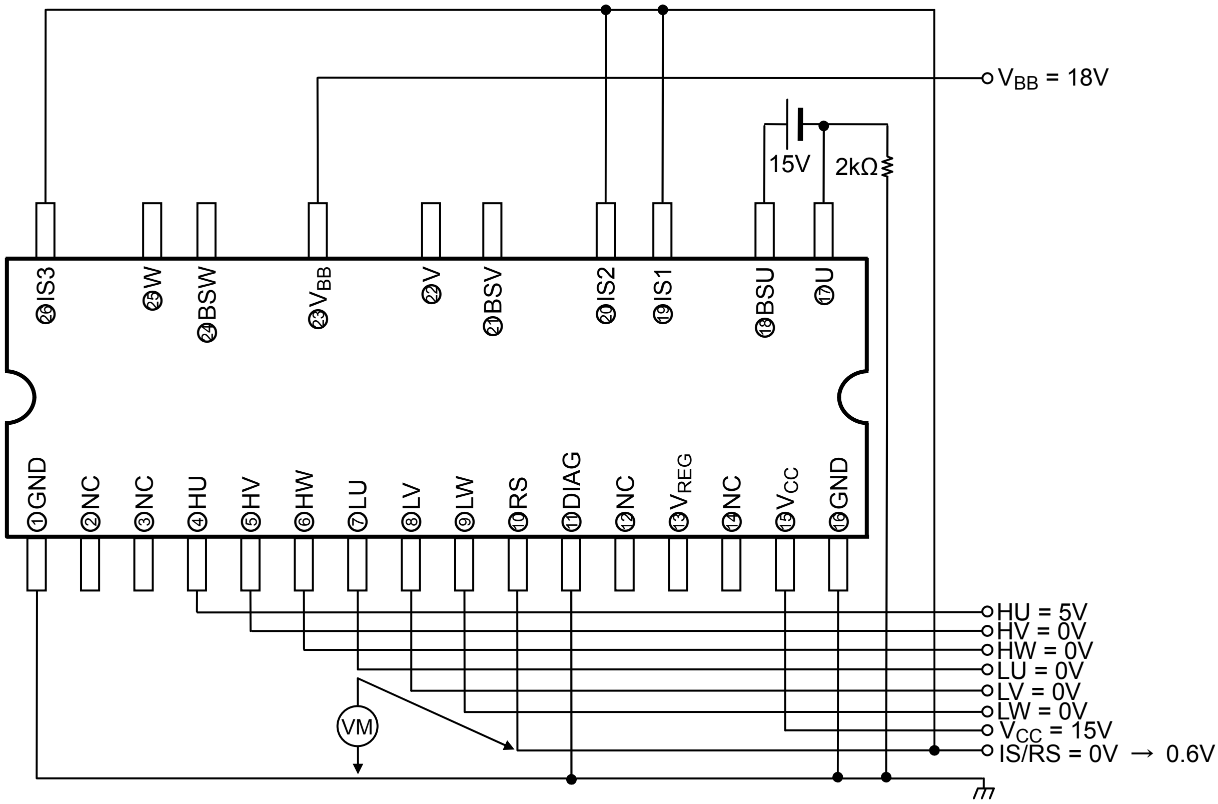
*Note: Sweeps the V_{CC} pin voltage from 15 V and monitors the U pin voltage. The V_{CC} pin voltage when output is off defines the under-voltage protection operating voltage. Also sweeps from 6 V to increase. The V_{CC} pin voltage when output is on defines the under voltage protection recovery voltage.

VBS Under-voltage Protection Operating/Recovery Voltage (U-phase high side)



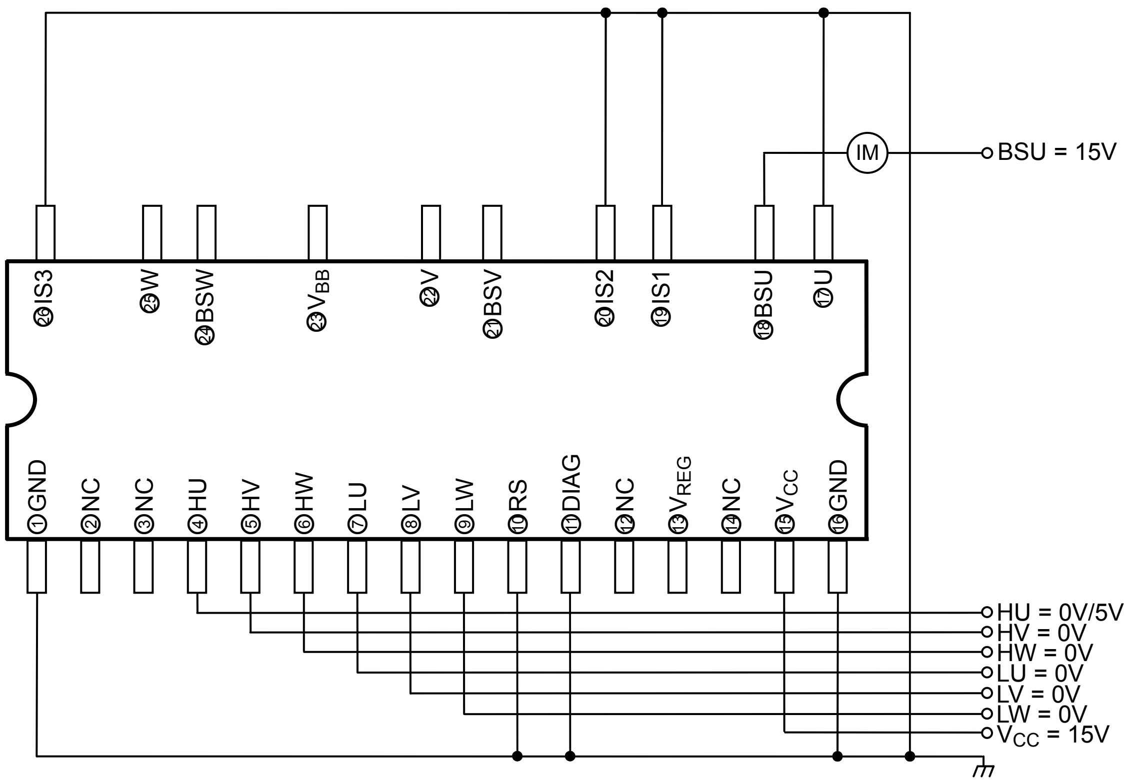
*Note: Sweeps the BSU pin voltage from 15 V to decrease and monitors the V_{BB} pin voltage. The BSU pin voltage when output is off defines the under voltage protection operating voltage. Also sweeps the BSU pin voltage from 6V to increase and change the HU pin voltage at 5 V→0 V→5 V each time. It repeats similarly output is on. When the BSU pin voltage when output is on defines the under voltage protection recovery voltage.

Current Limit Operating Voltage (U-phase high side)

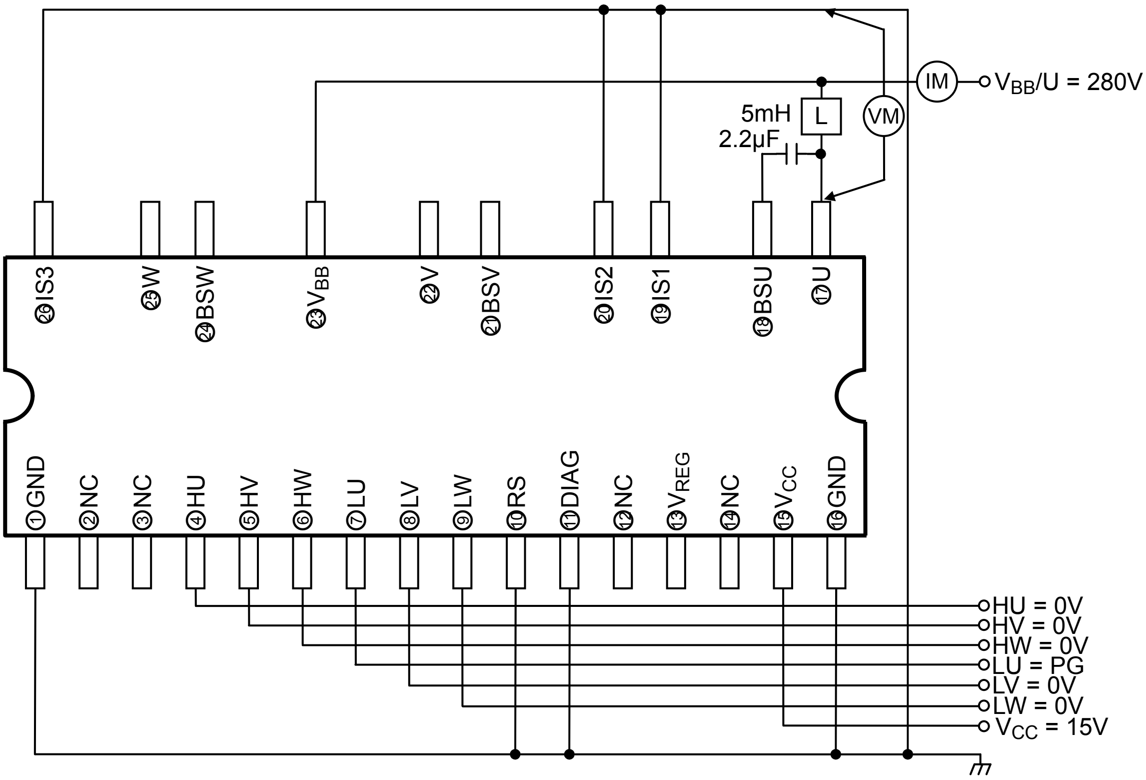


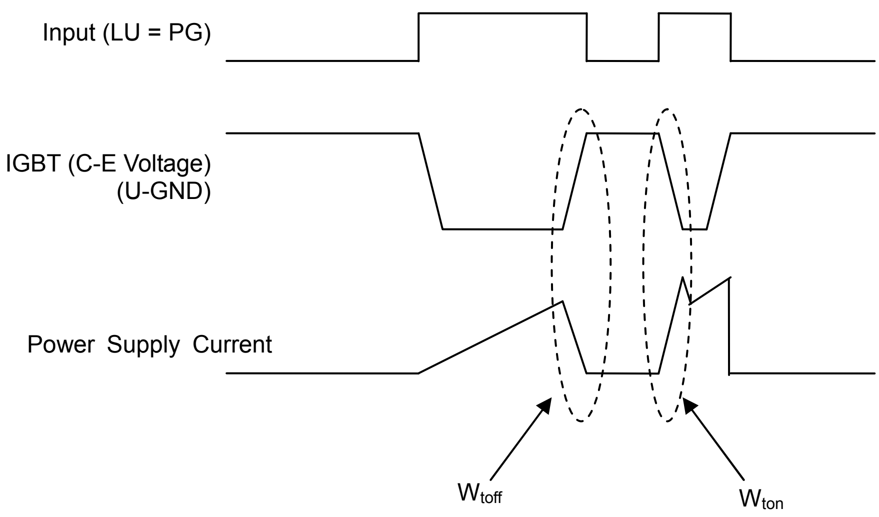
*Note: Sweeps the IS/RS pin voltage and monitors the U pin voltage.
The IS/RS pin voltage when output is off defines the current control operating voltage.

Bootstrap Current Dissipation (U-phase high side)



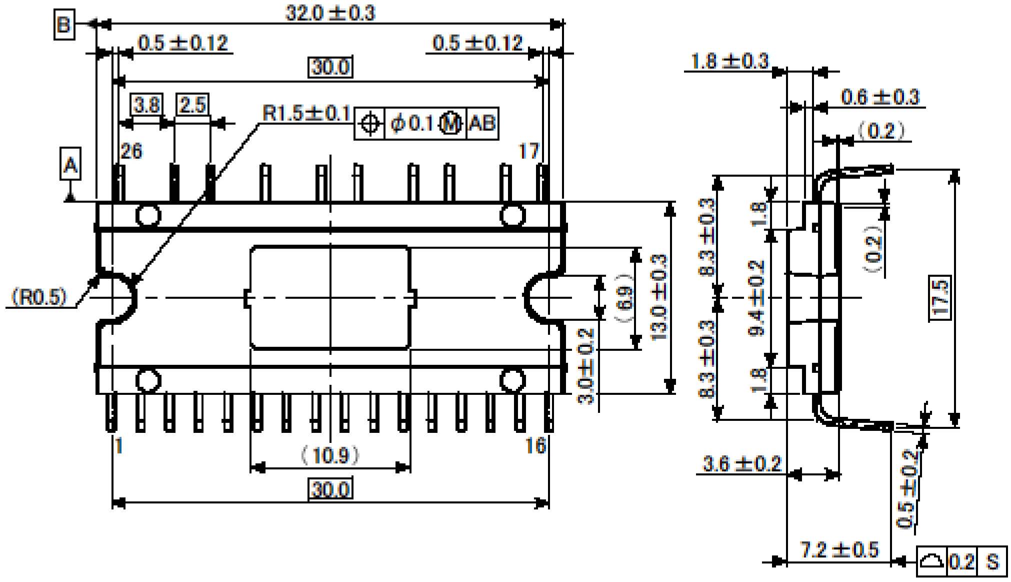
Turn-ON/OFF Loss (low side IGBT + high side FRD)

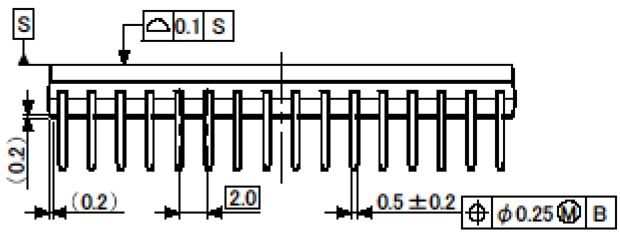




Package Dimensions

HDIP26-P-1332-2.00 Unit: mm





Weight: 3.8 g (typ.)

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